Syn-Sedimentary Tectonics of the Jurassic Sedimentary Sequence in the Northern Viking Rift Graben (North Sea), Producing Asymmetrical Stratal Packages*

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Abstract

The Permo-Triassic and the Upper Jurassic rift-phases in the Northern North Sea have been regarded as a time of crustal scale thermal cooling with uniform basin-wide subsidence, and with only minor tectonic movement along some of the larger basin faults. Well data indicate, however, that fault block rotation occurred on both field and regional scale during deposition of the Jurassic strata. This shows that the transition from thermal cooling and subsidence following the Permo-Triassic rift-phase to renewed rifting was gradual and complex. On a regional scale, the Jurassic package defines a profound westward thickening sedimentary wedge (3 times), indicating rotation of a Permo-Triassic mega-block. The prograding Rannoch and Etive formations of the Brent Group show a uniform east-west thickness distribution indicating no tectonic influence during deposition, as they were deposited within a relative short time-period. However, the Ness, Tarbert and Heather formations show a dramatic asymmetrical east-west (5 times thickness increase) strata wedge indicating the initiation and escalation of tectonic extension leading up to the Upper Jurassic phase of rifting. The tectonic extension caused an increase in relative sea-level that forced the Brent Delta to switch from progradation to aggradational stacking style (seen in a S-N direction) and finally to retrogradation and drowning of the Brent Group.

On field-scale, the Upper Jurassic rifting above the Etive Formation is clearly seen from inter-well correlation and in some cases in seismic sections. Here, the Ness-Tarbert-Heather succession shows considerable thickness differences (6 times) across faults in both data sets within a few kilometers.

In contrast to passive margins, extensional basins undergoing thermal cooling and rifting have a different style of sedimentary infill (facies architecture, N/G ratios, etc.). Where the sedimentation rates are less than the local subsidence (underfilled basin), the structural relief will control the drainage pattern. When near equal, a segregation of the facies distributions will occur (balanced filled), and when the sedimentation rate exceeds the subsidence rate (overfilled basin), the facies distribution will be governed by autocyclic processes. The studied Jurassic package shows these interesting aspects and it is important to take these aspects into account when evaluating the reservoirs and potential of adjacent exploration areas.

Selected Reference

Helland-Hansen, W., M. Ashton, L. Lomo, and R. Steel, 1992, Advance and retreat of the Brent Delta; recent contributions to the depositional model: Geological Society Special Publications, v. 61, p. 109-127.

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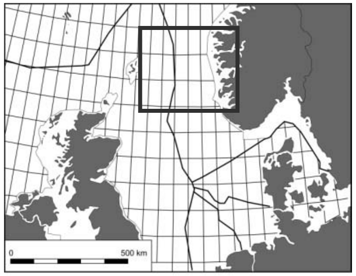
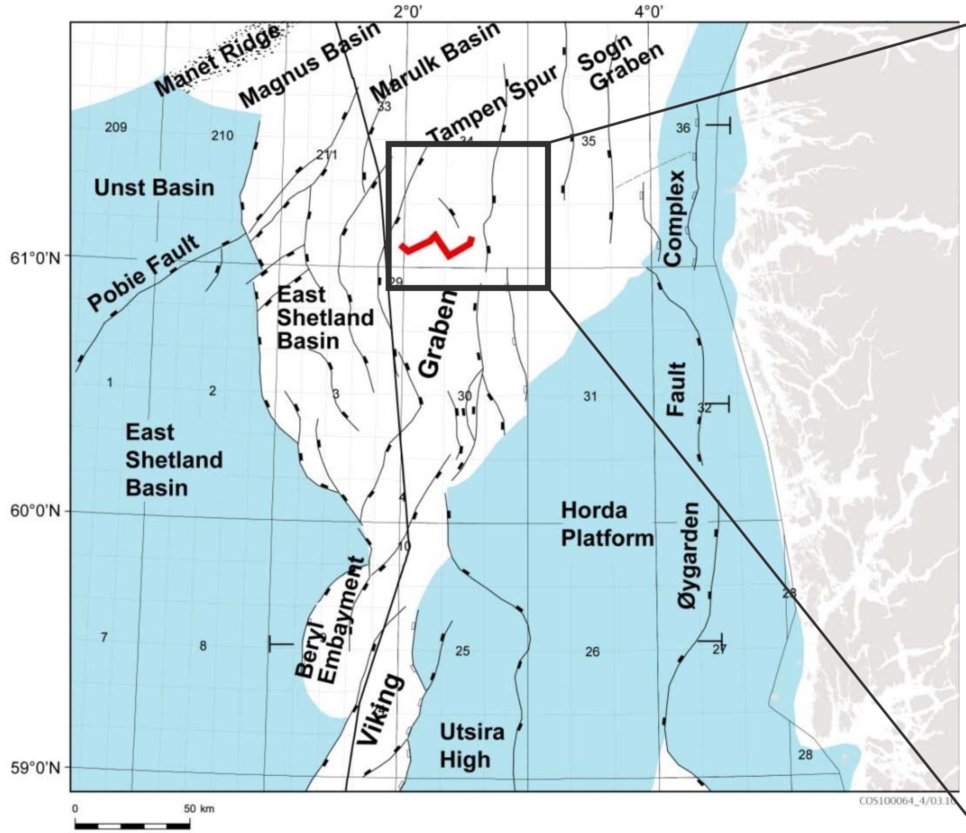
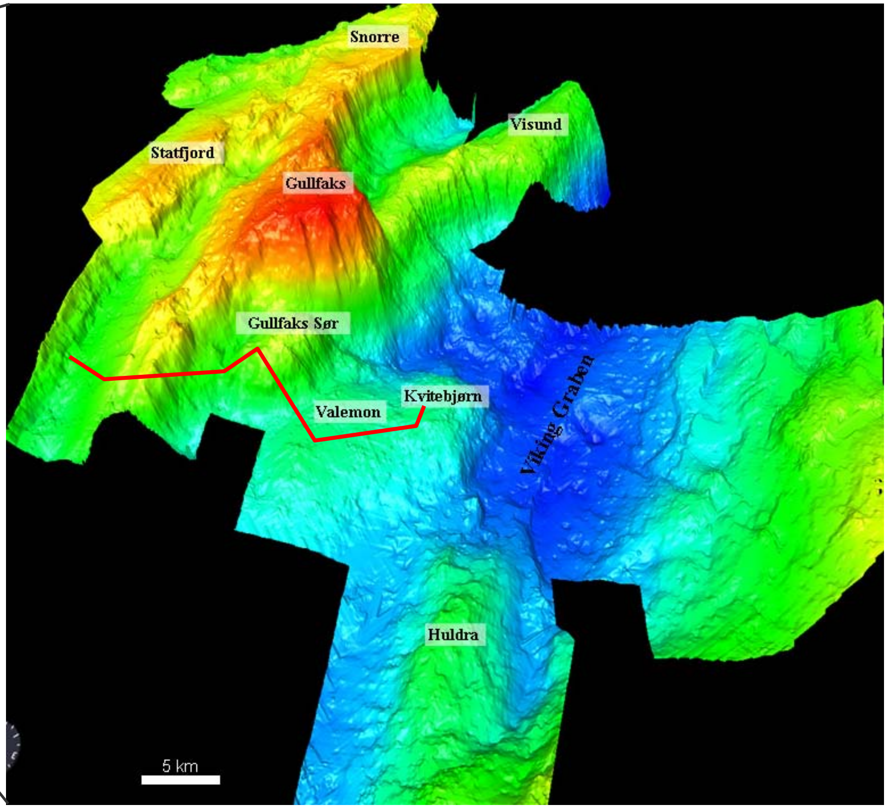
Outline

- Rationale
- Geological setting
- The Jurassic package on Tampen Spur – regional scale
- Field-scale example – Kvitebjørn Field
- Upper Brent palaeogeographical maps
- Conclusions

Location map



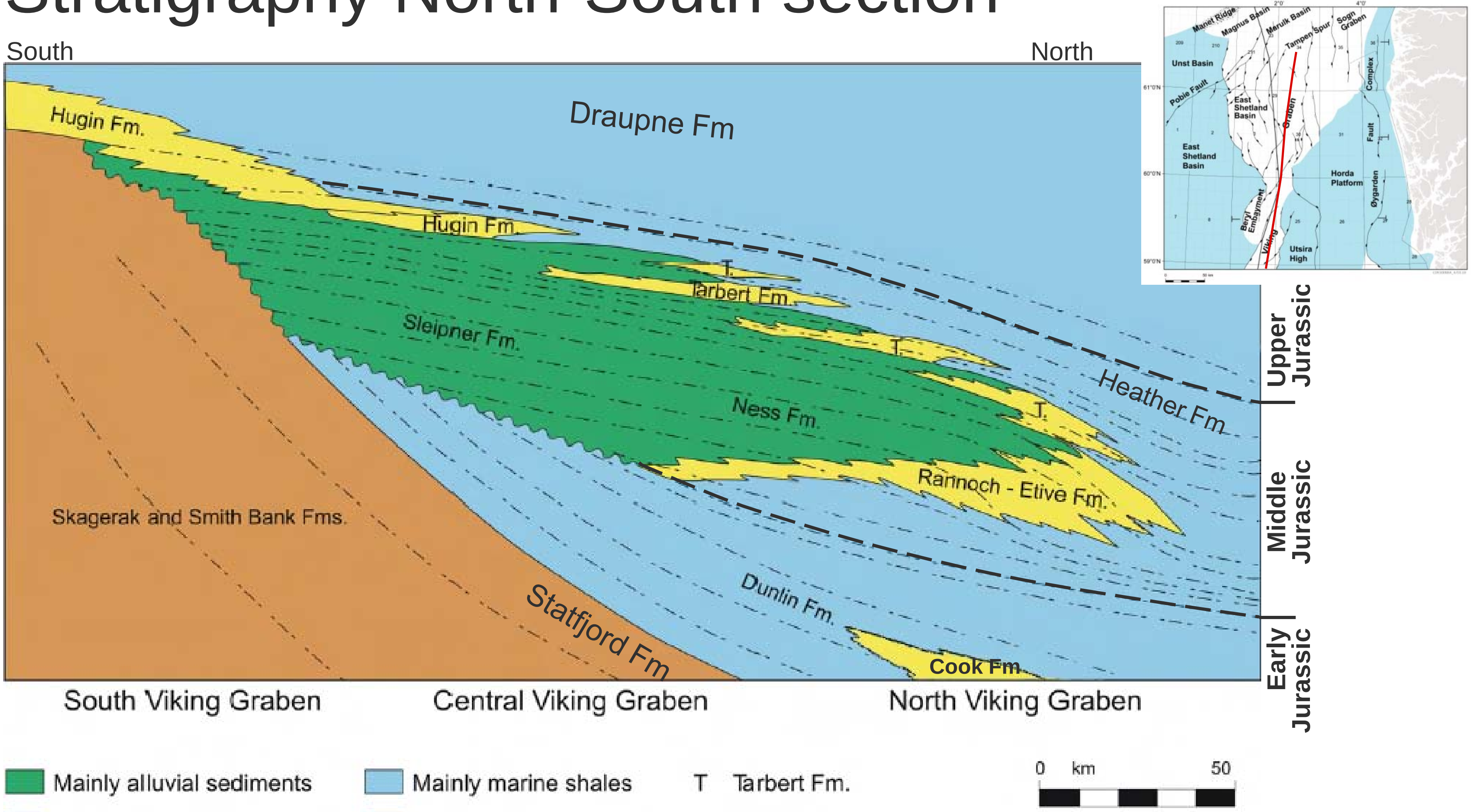




Main Jurassic faults — Well correlation transect

Base Cretaceous time map

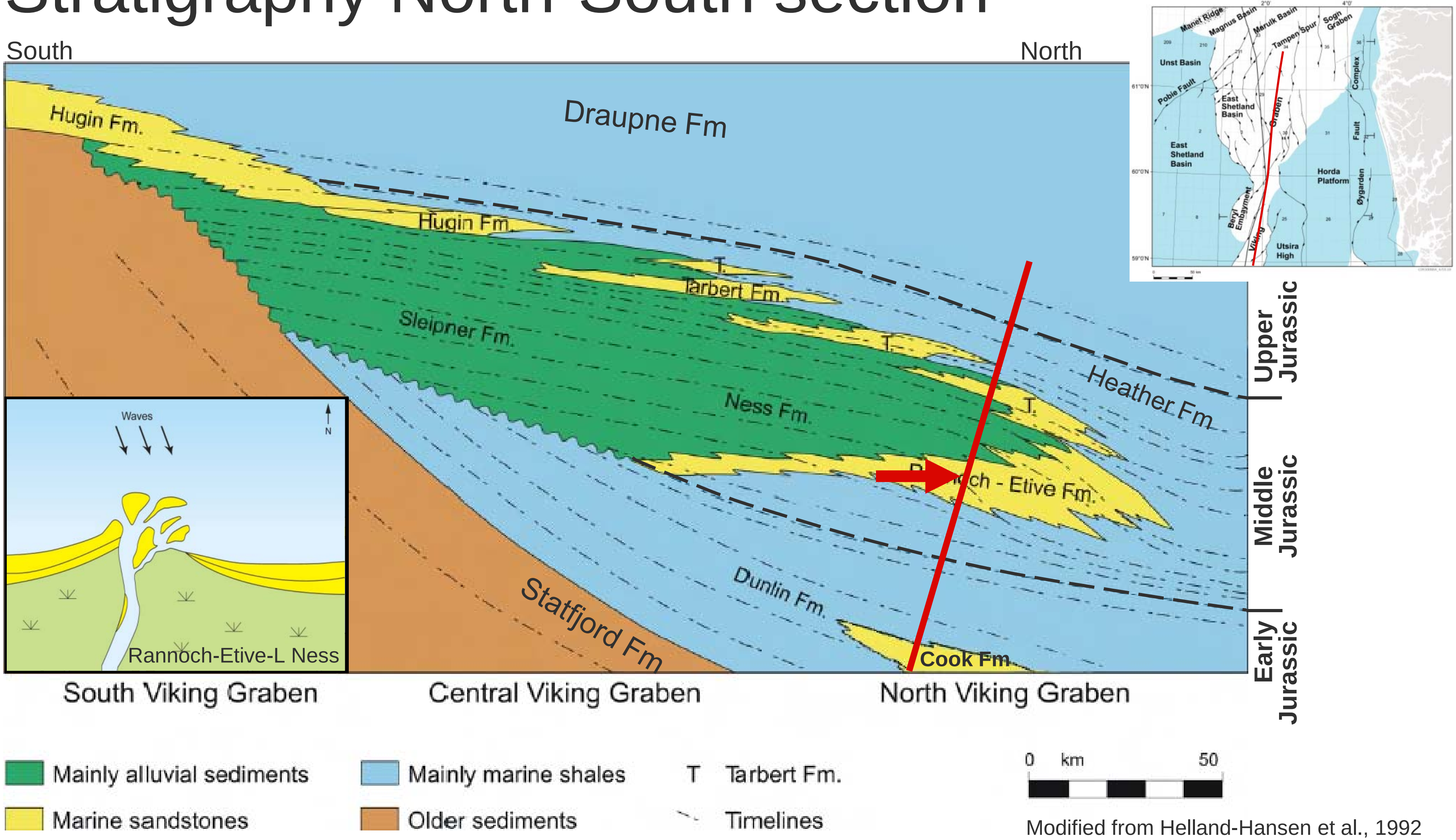
Stratigraphy North-South section



Modified from Helland-Hansen et al., 1992

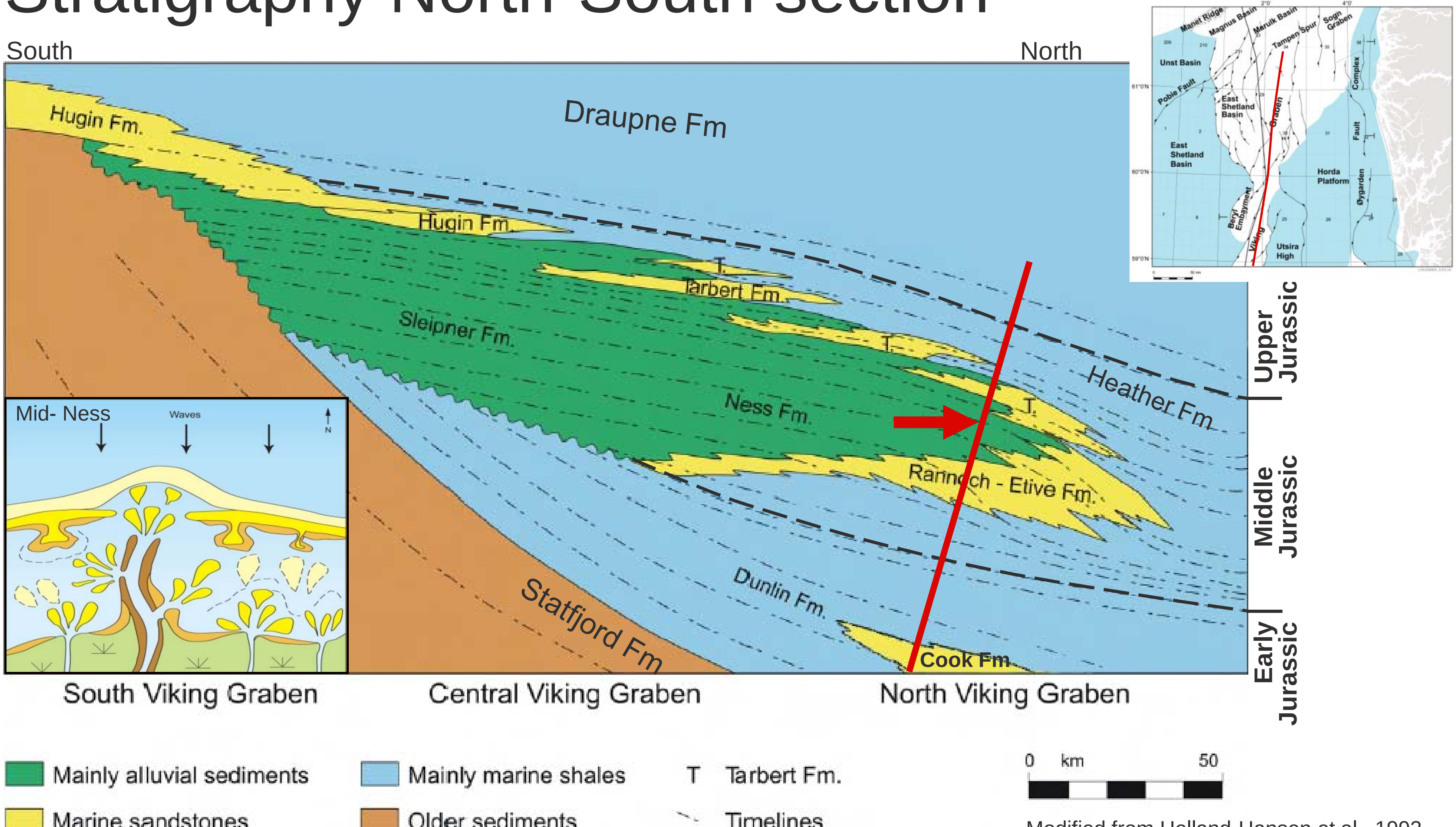
Statoil

Stratigraphy North-South section



Modified from Helland-Hansen et al., 1992

Stratigraphy North-South section



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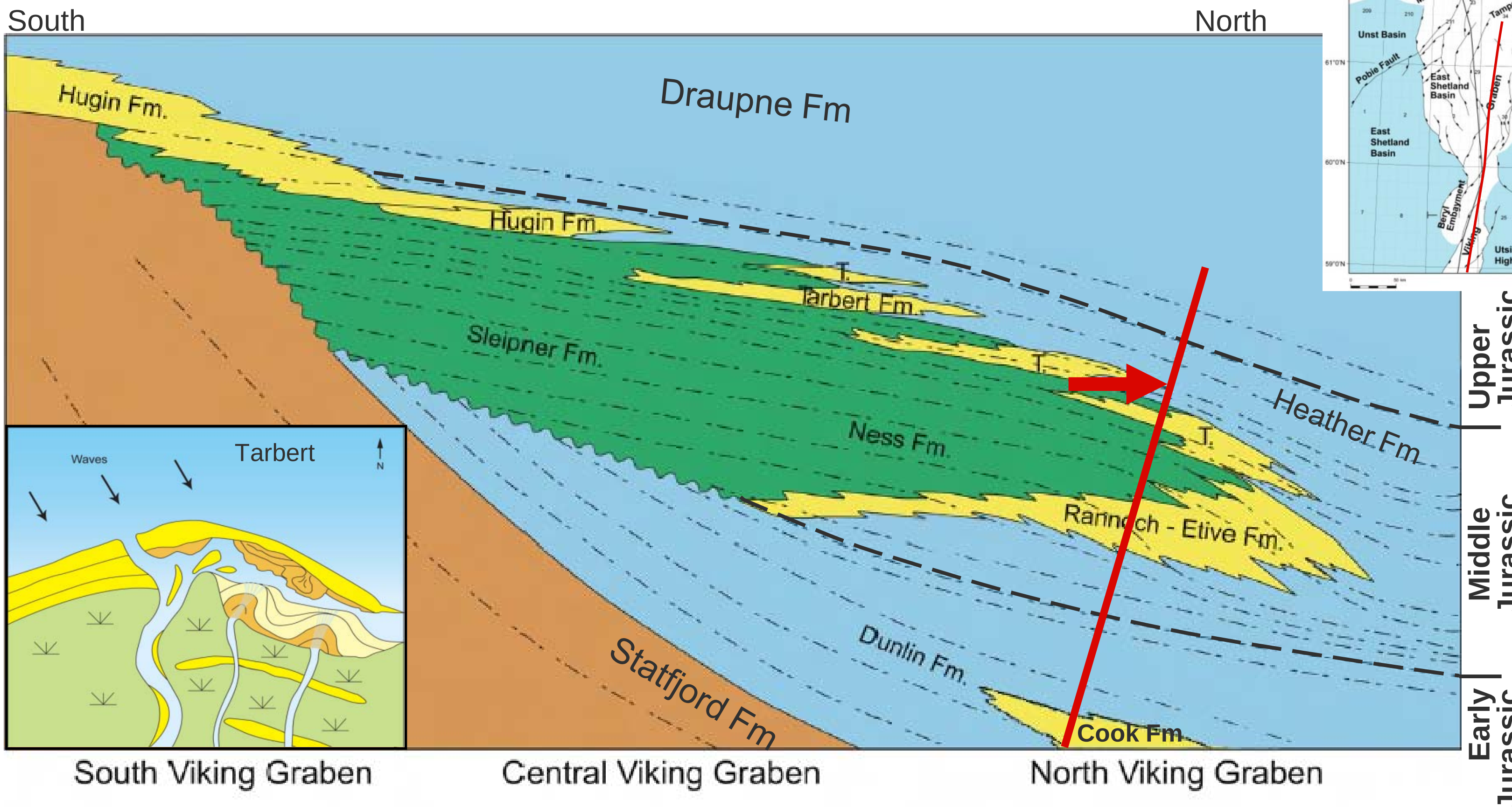
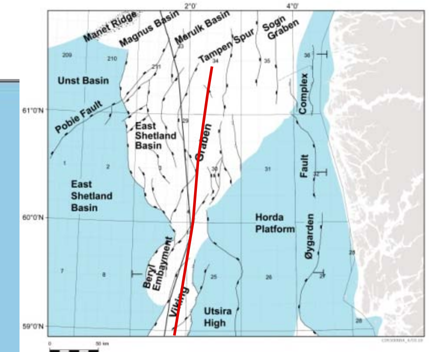
Stratigraphy North-South section





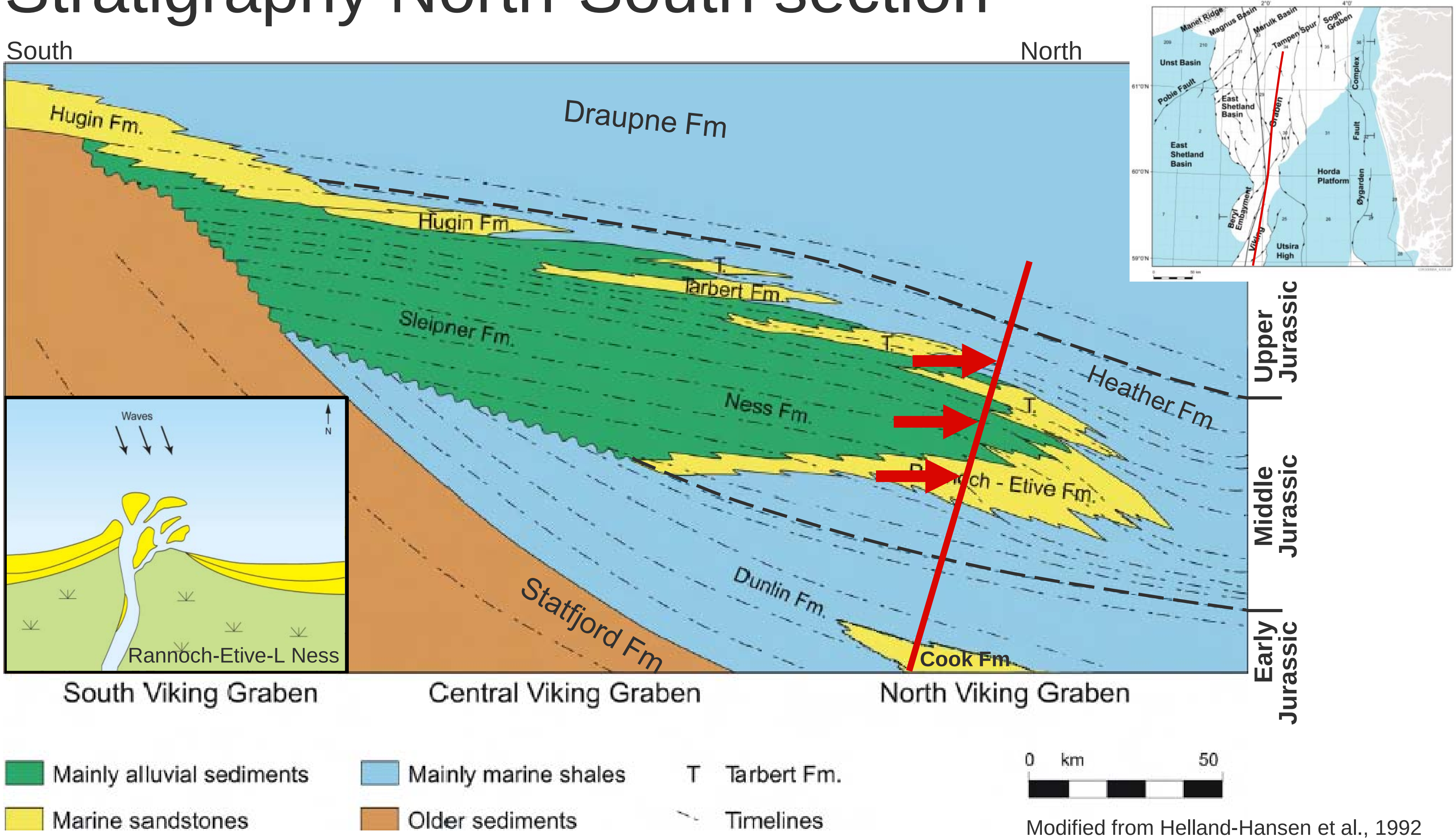
Mainly alluvial sediments
Marine sandstones
Mainly marine shales
Older sediments
T Tarbert Fm.
Timelines

0 km 50

Modified from Helland-Hansen et al., 1992

Statoil

Stratigraphy North-South section



Modified from Helland-Hansen et al., 1992

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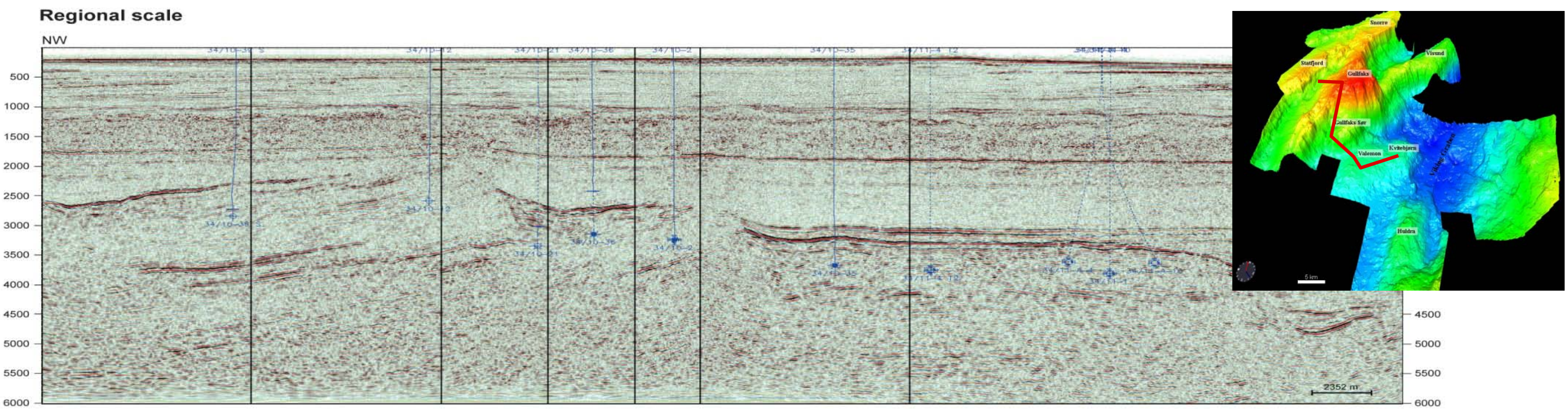
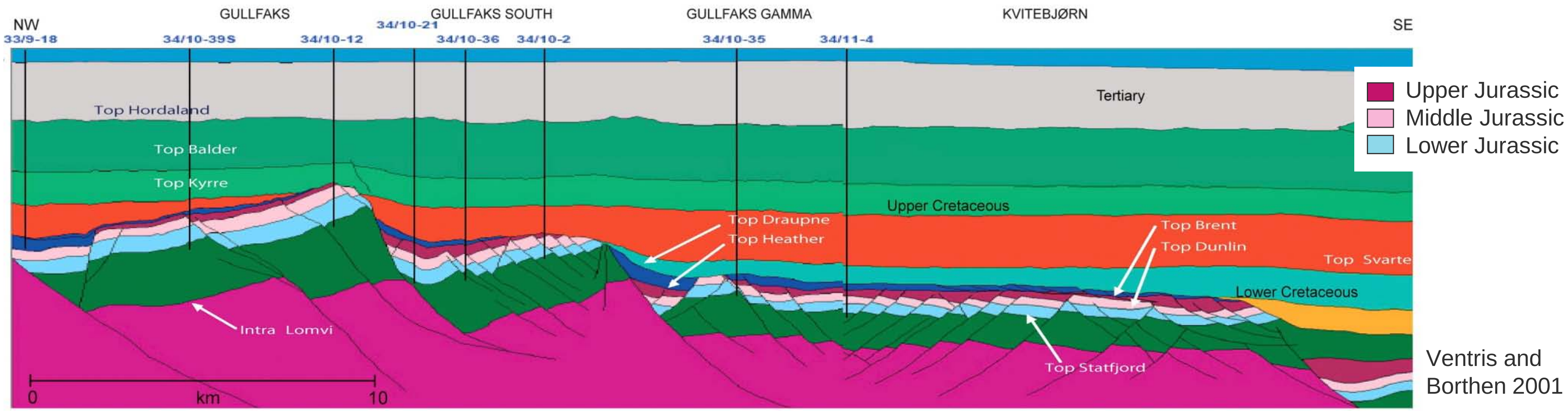
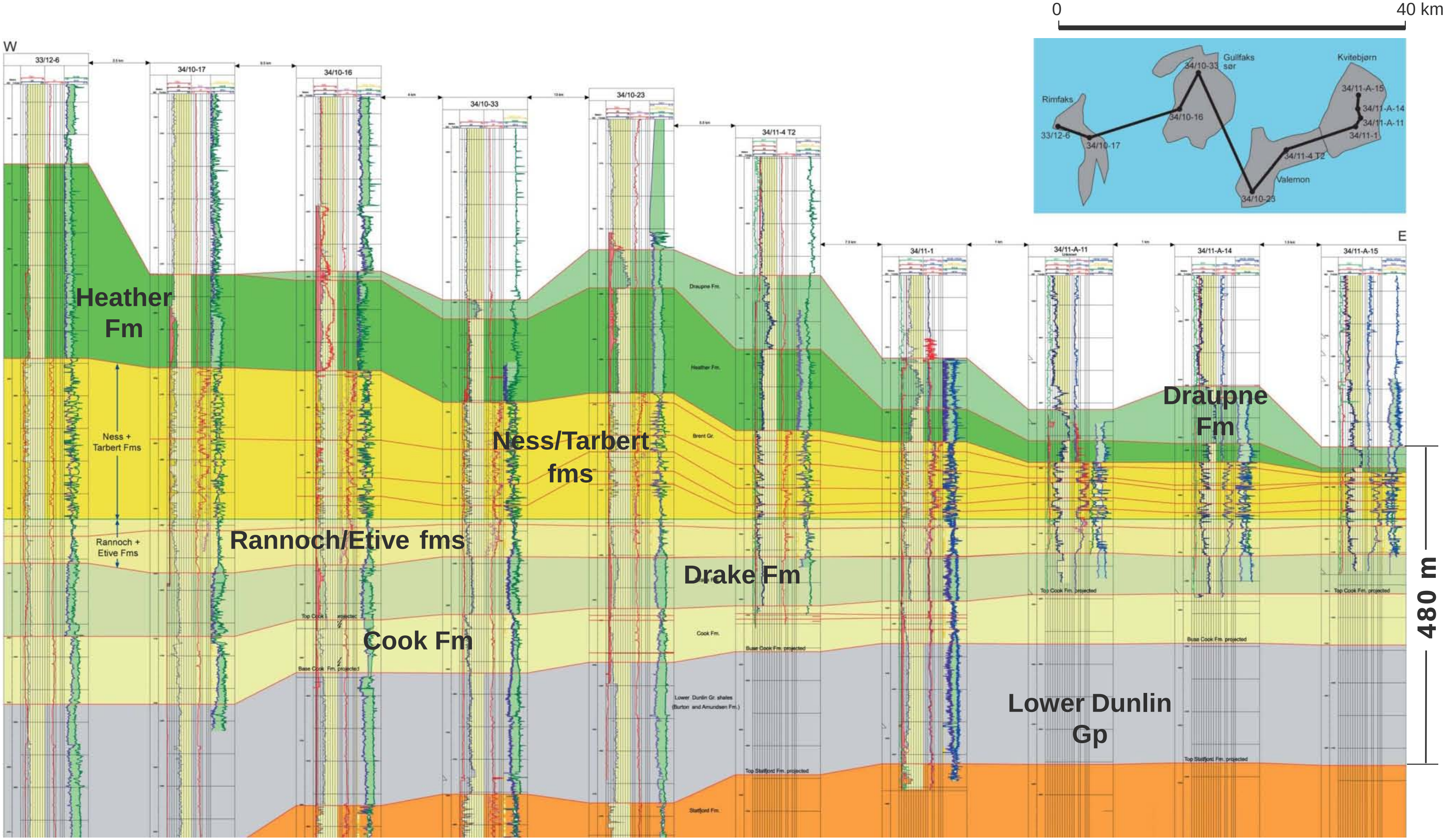
Permo-Triassic megablock – Tampen





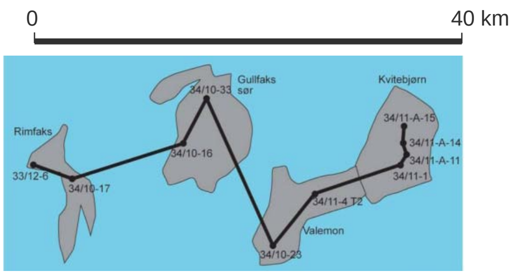
Ventris and Borthen 2001

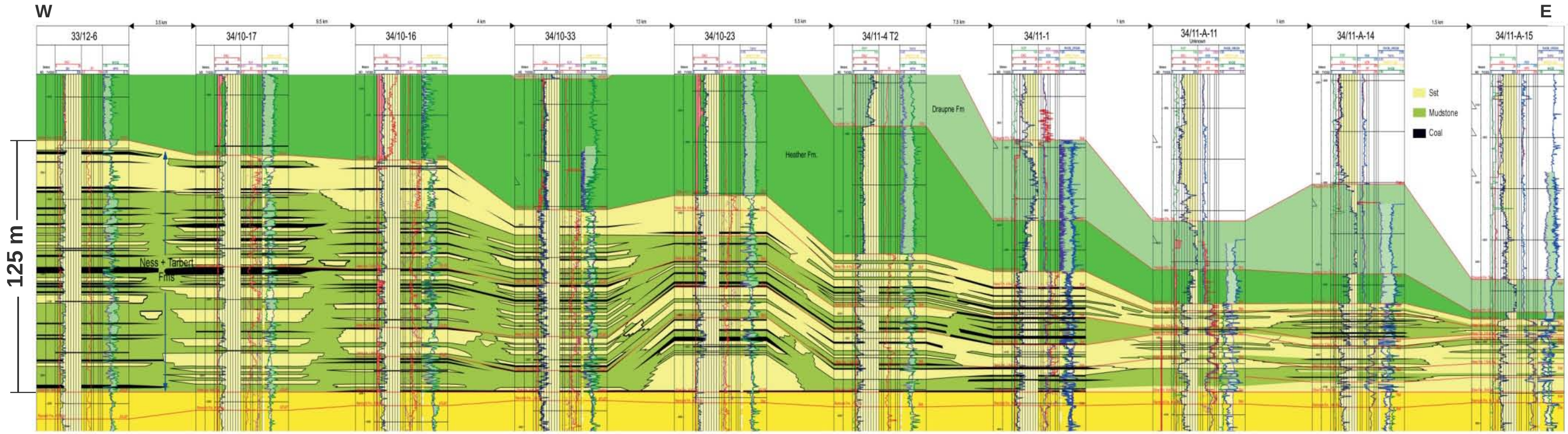
Well-correlation on formation scale



Statoil

Lithology distribution of the Ness/Tarbert fms





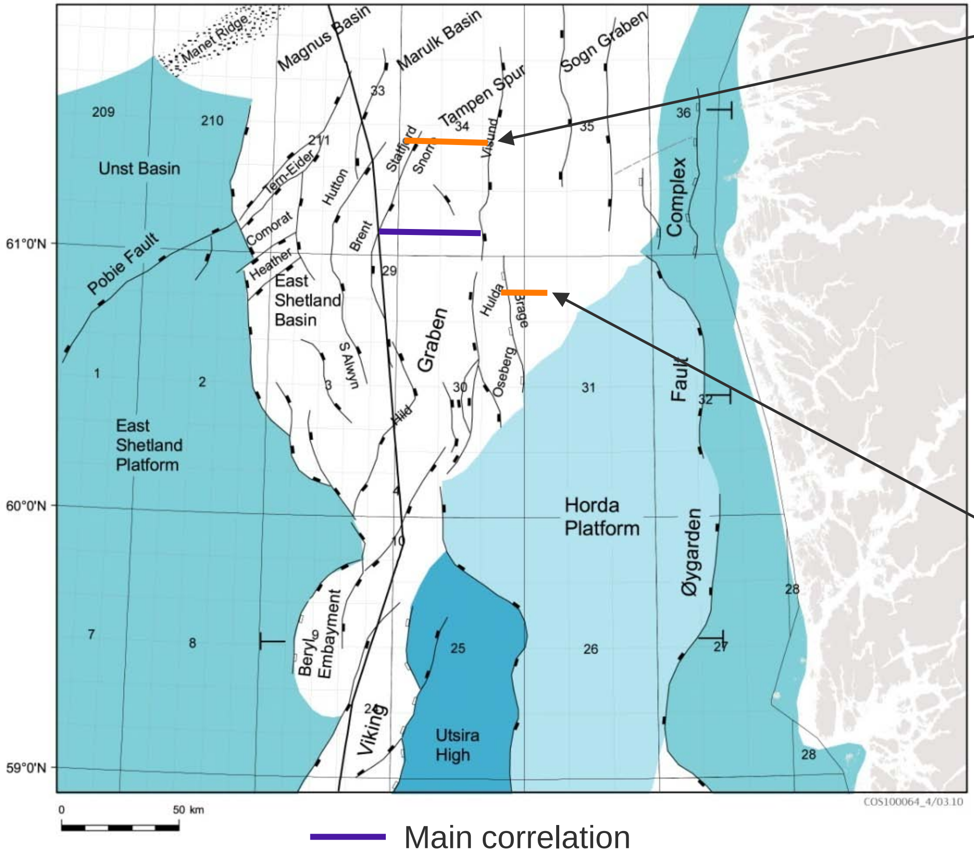
Westward increase of:

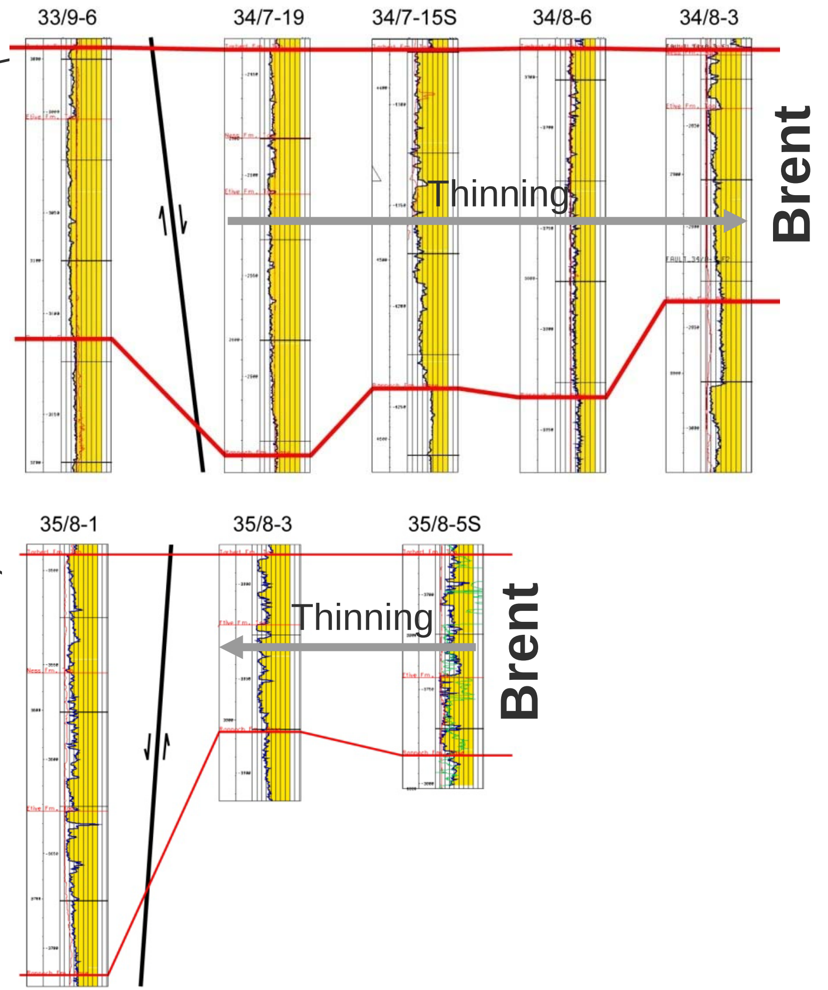
- More and thicker coal development westward
- Thicker mud units (lower N/G)
- Fluvial strata

Eastward increase of:

- Wave-reworked strata
- Higher N/G
- Higher connectivity

Sedimentary wedges in other locations





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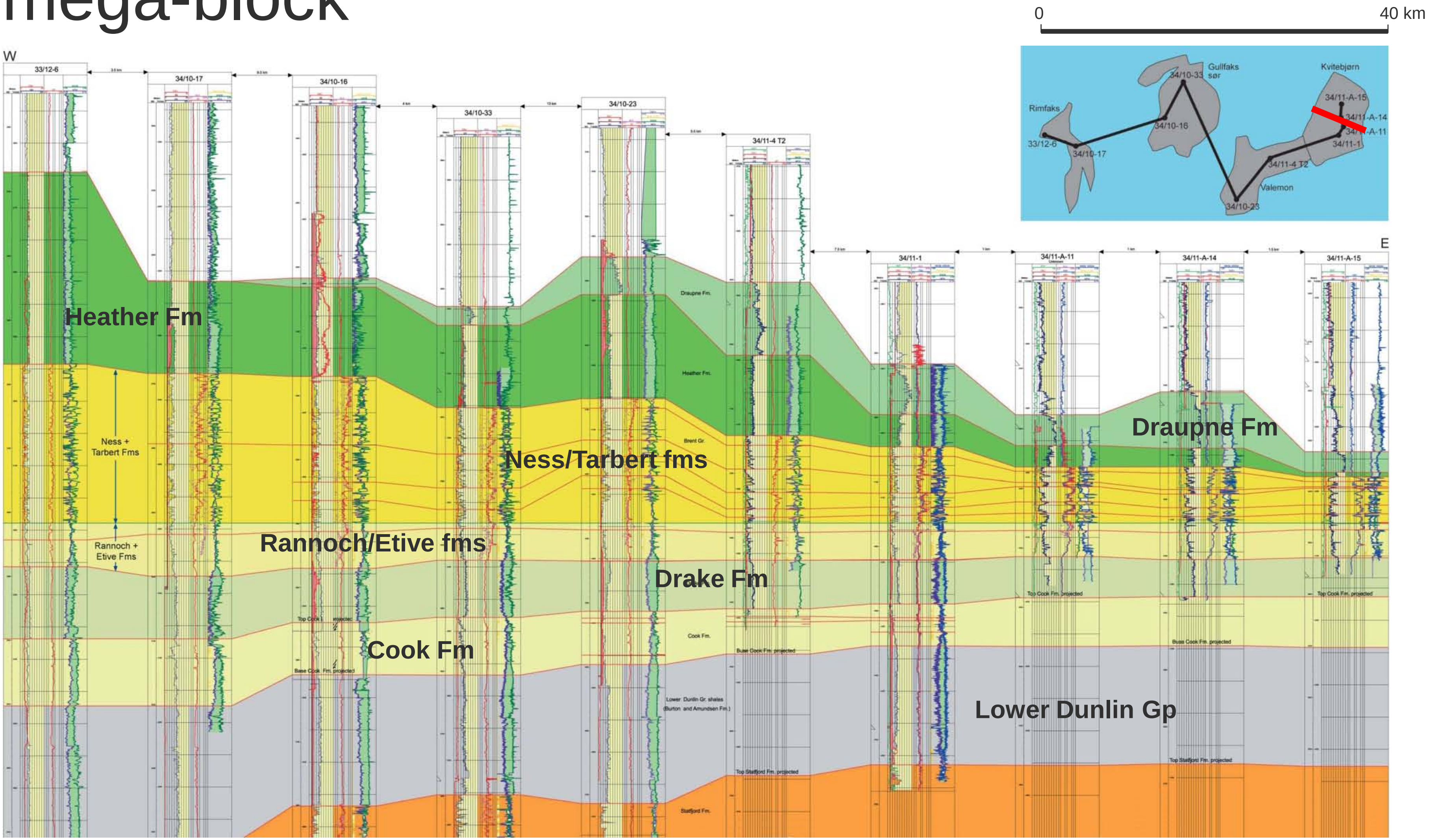
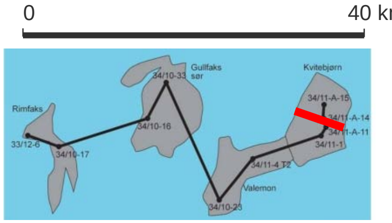
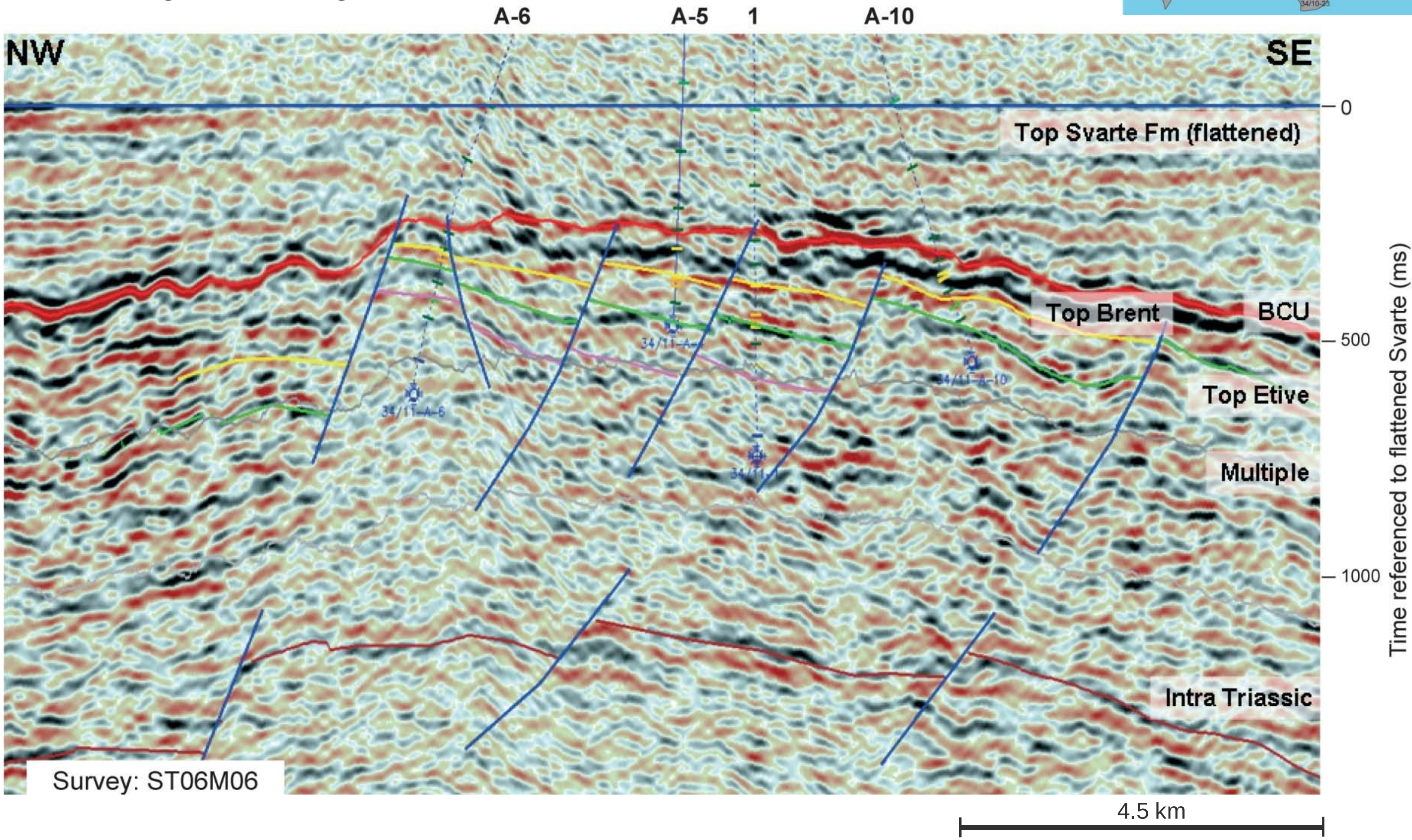
The crest of the Permo/Triassic mega-block



Arbitrary NW-SE seismic line across the Kvitebjørn Field

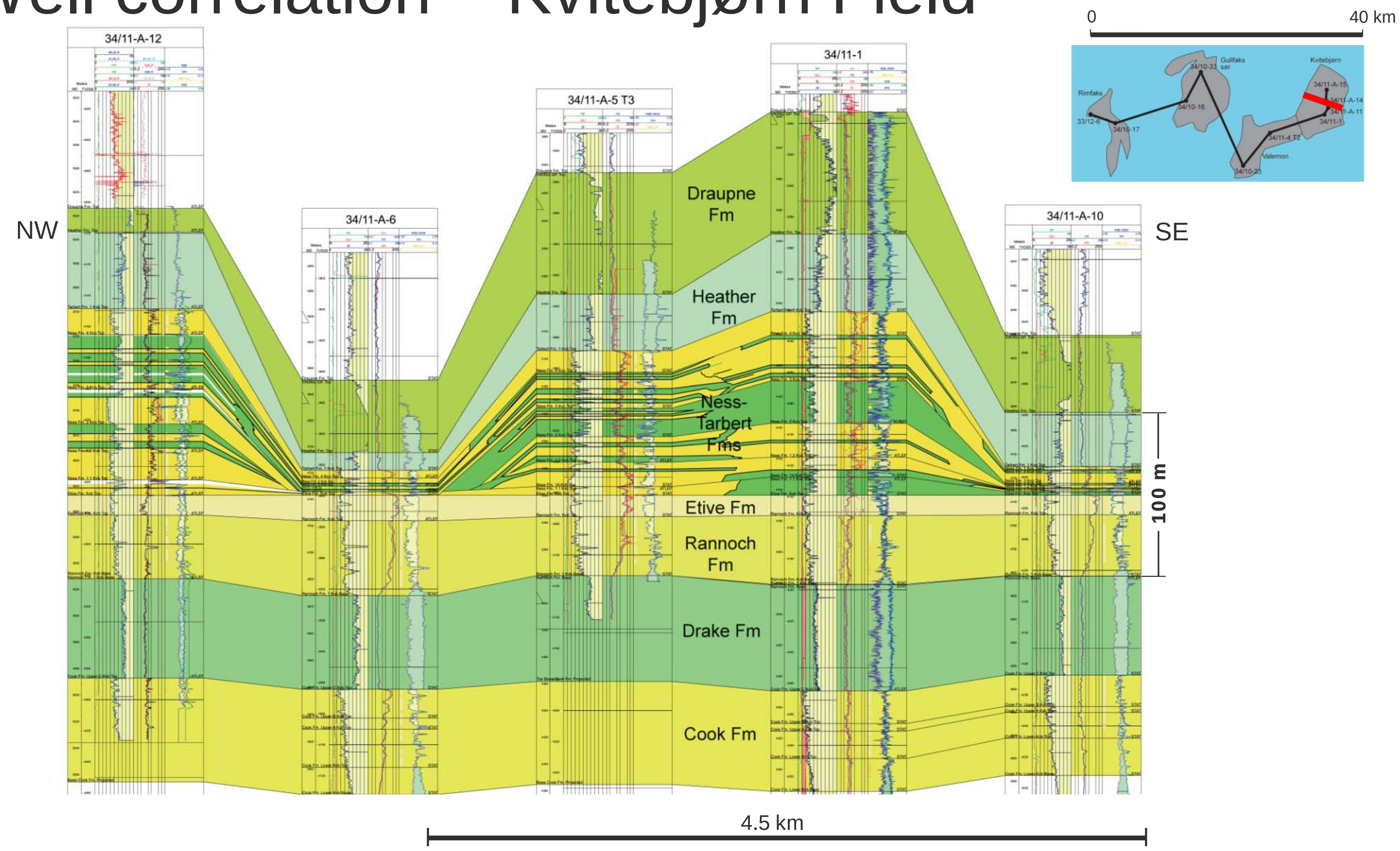
Asymmetric wedge thickening towards the east



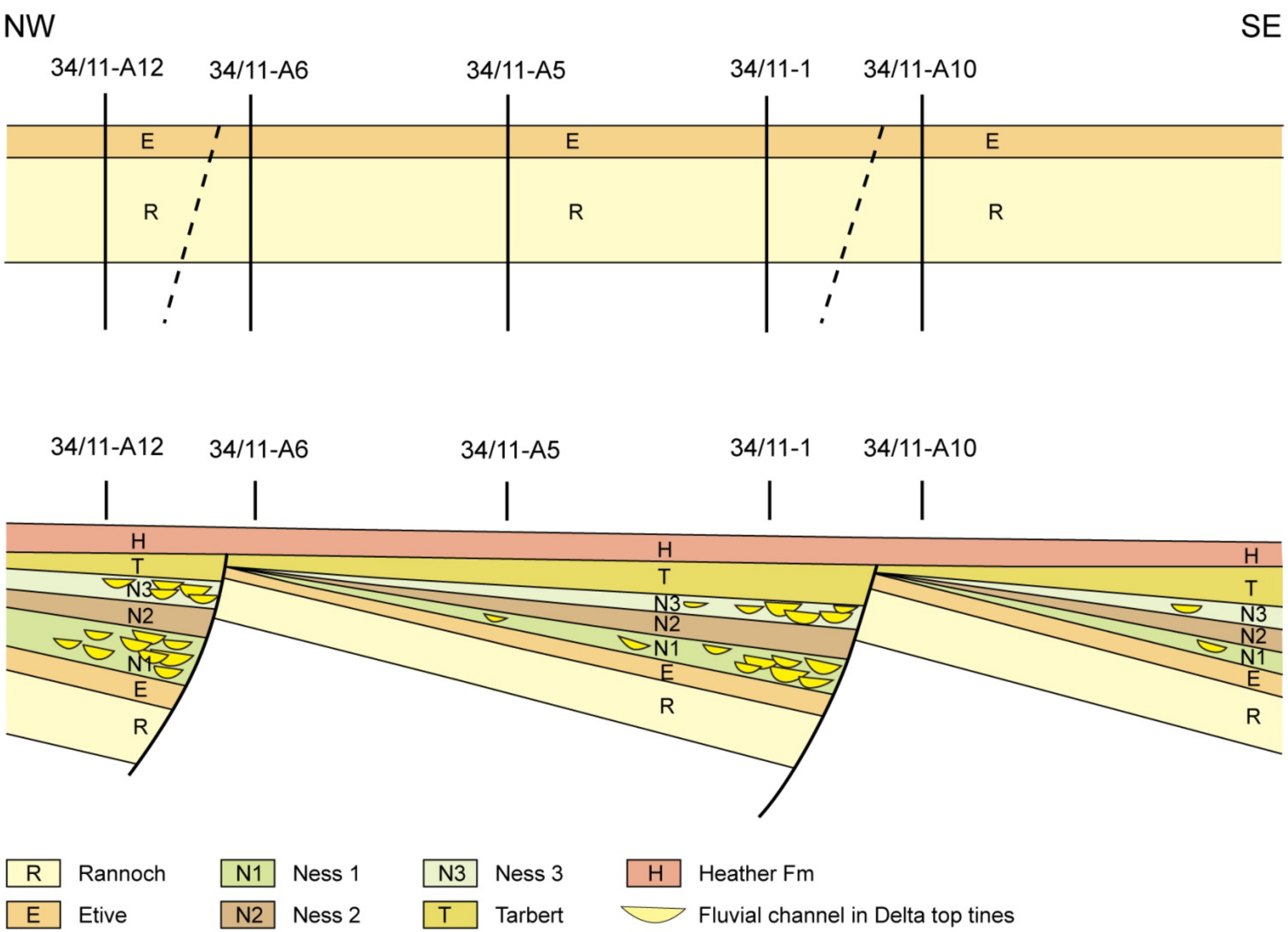


Statoil

Well correlation – Kvitebjørn Field

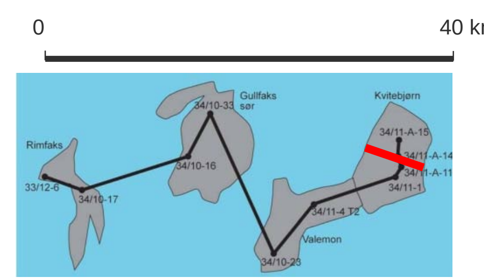


From pre- to syn-sedimentary antithetic fault movements

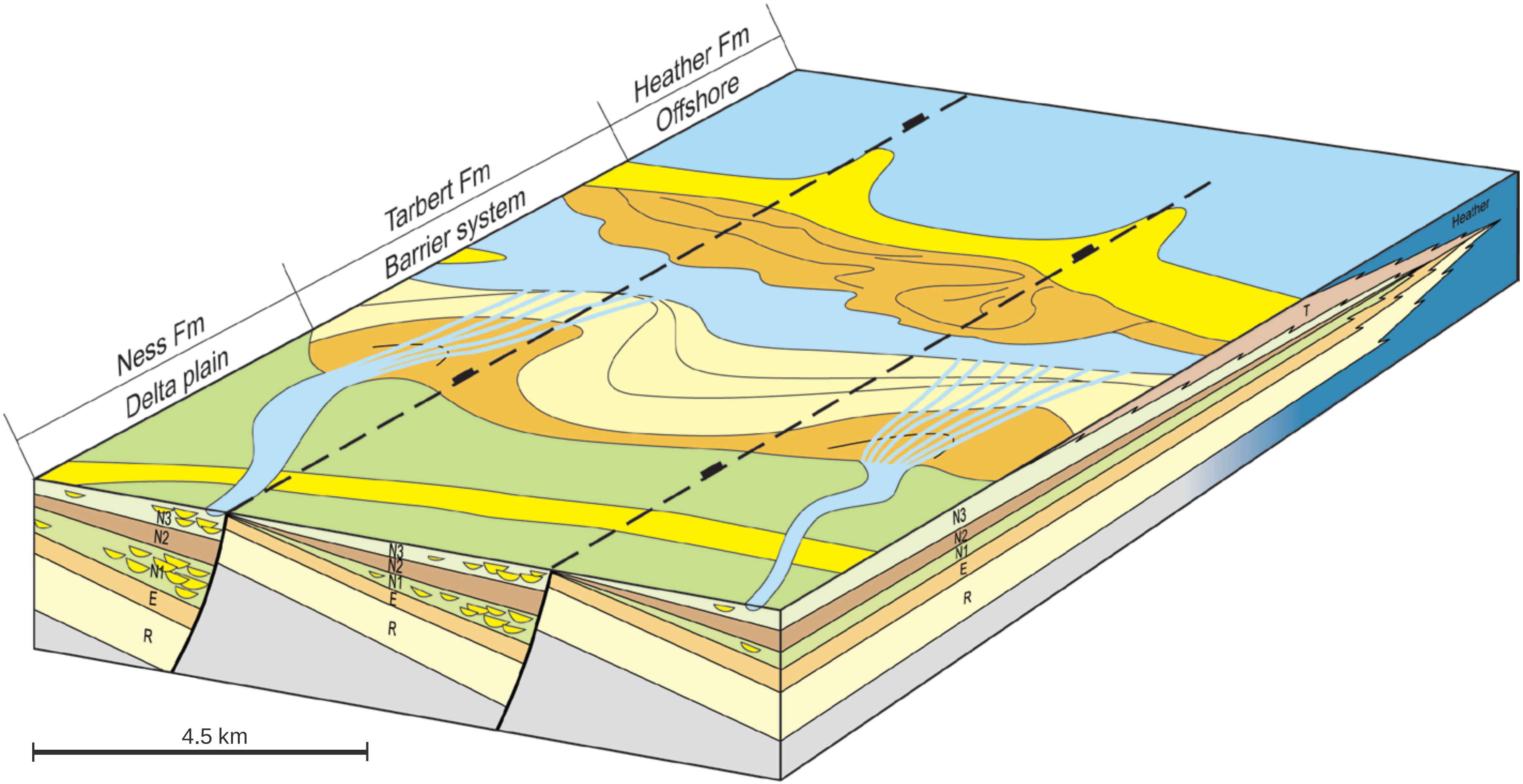


Rannoch/Etive fms ~ 2-3 my

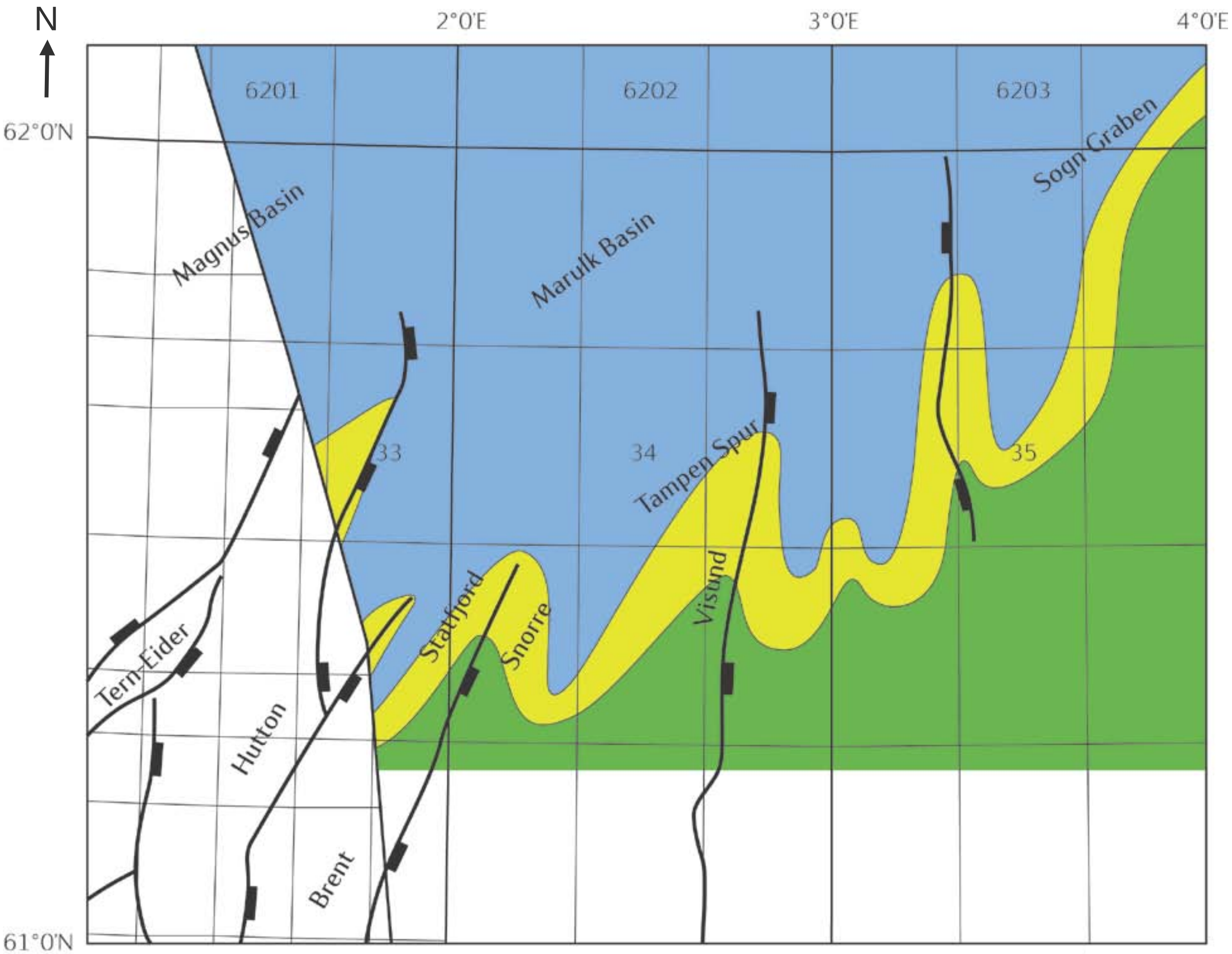
Ness/Tarbert fms ~ 8 my

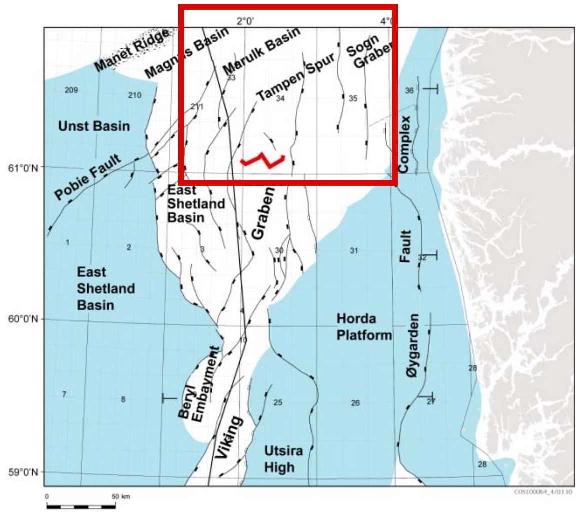


Ness-Tarbert in antithetic rotated fault blocks at Kvitebjørn Field – syn-rift



The southward retreat of the Brent delta (Bathonian)





Heather Fm
Offshore mudstones

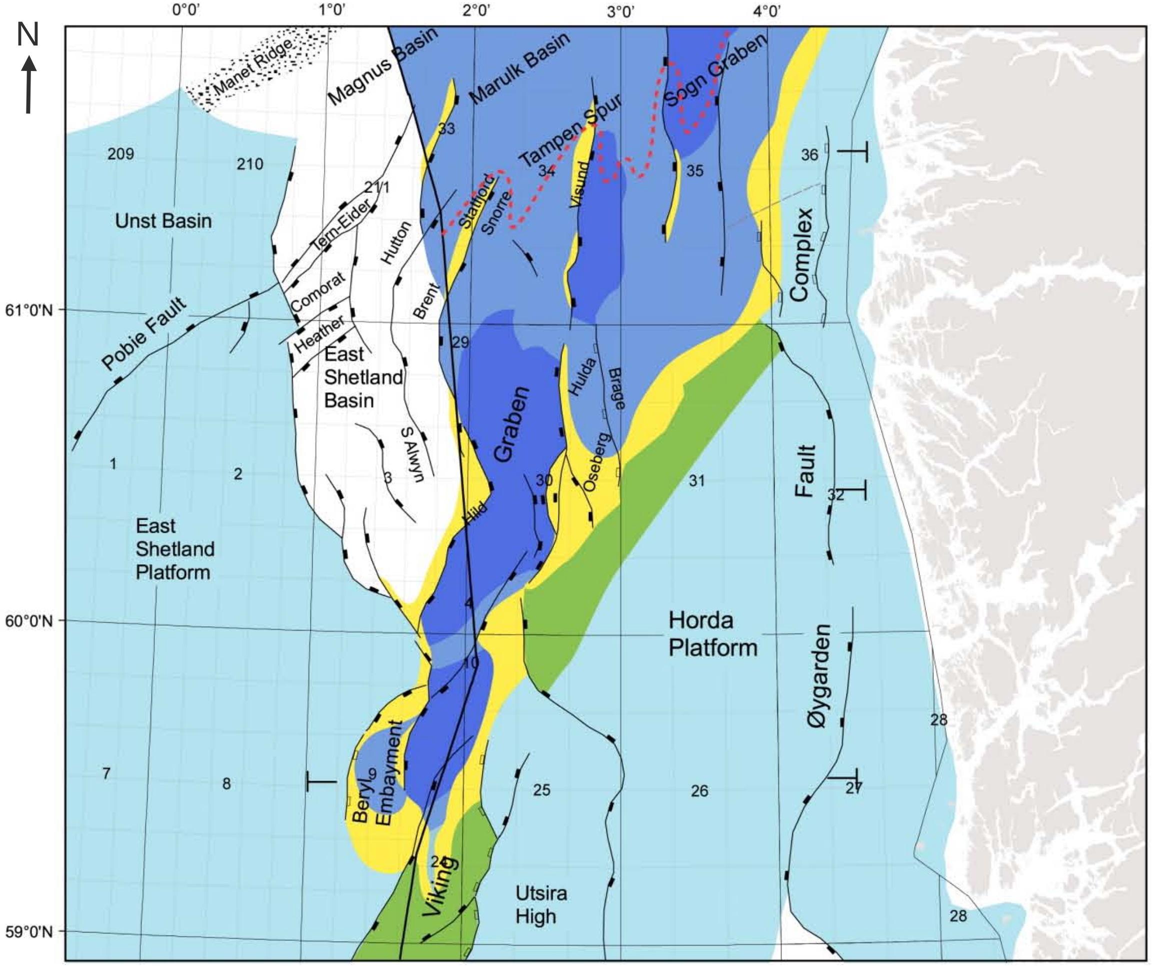
Tarbert Fm sands

Ness Fm Alluvial plain

Reactivated
Permo-Triassic faults in
Jura

The Early Callovian Viking Graben

N



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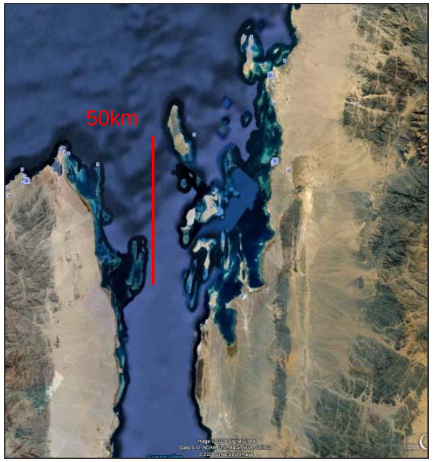

Gulf of Suez

- Position of the previous Bathonian coastline
- Major intra-basinal highs
- Offshore mudst. High subsidence
- Offshore mudst. Less subsidence
- Tarbert Fm sands
- Ness Fm Alluvial plain
- Main Jurassic faults

0 50 km

Statoil

Conclusions

- The Permo-Triassic megablocks subsided asymmetrically during the Jurassic producing a profound thickness increase in an east-west profile as the Kvitebjørn-Gullfaks case.
- The Lower Ness Fm marks the Middle-Jurassic initiation and escalation of extension that forced the Brent Delta to aggrade and later retreat southwards in the syn-rift phase and a profound Ness Fm to Heather Fm wedge developed east- west
- The Ness-Tarbert fms wedge show facies segregation -N/G trends and such and represents a balance between accommodation and sediment supply
- In the crestal part of the megablock (Kvitebjørn area) faults are developed in early syn-rift strata in the Ness-Tarbert fms leading to a complex Brent stratigraphy
- The syn-rift phase created an irregular coastline in the Tarbert Fm and later fault-crest attached sands as footwall islands